Improved Emergency Locator and Tracking Beacons for Aircraft

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Locating Aircraft

- Air traffic control uses secondary radar and mode-C transponders on aircraft
- Provides 3-D location of aircraft in bearing, range, altitude
- Emergency locator transmitters provide location of crashed aircraft via satellite
- There is a need for a low cost system that can locate all aircraft at all times.

Aircraft Beacons

- Aircraft can have a wide variety of position reporting and identification beacons
- IFF
- Mode-C transponder
- Mode-S transponder
- Emergency Locator Transmitter (ELT)
- – 121.5 MHz (analog)
- – 406 MHz (digital, GPS)

Aircraft Beacons

- Mode-C transponder: $1,500
- Transmits ID and altitude
- Position is found via interrogation with directional antenna, range finder
- Mode-S transponder: $???
- Similar to mode-C plus GPS readout of position (squitter mode)
- Transponders can be turned off in cockpit

Aircraft ELT Beacons

- ELT – 121.5 MHz ~ $500
- Repeated tone, battery supported
- Located by search and rescue receiver
- Low earth orbit satellite reports signal
- ELT – 406 MHz ~$2,500
- Transmits coordinates from GPS receiver
- Relayed by GEO Satellite

Capstone Experiment

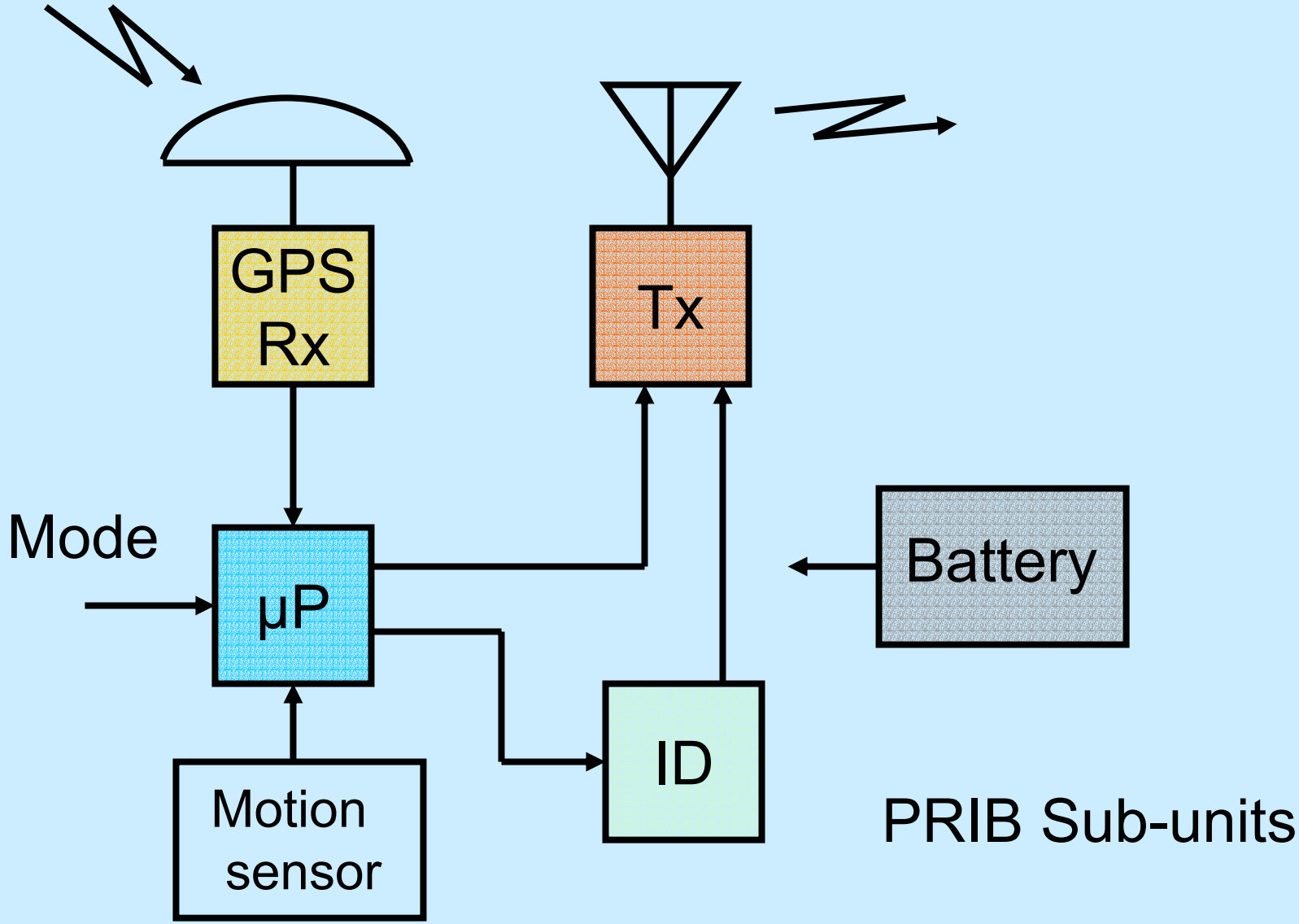
- Capstone Experiment uses Mode-S transponders on aircraft in Alaska
- Mode-S transponder transmits GPS location of aircraft (squitter mode)
- Strategically placed receivers relay position data to ATC
- Supplements limited secondary radar coverage
- Very successful demonstration

PRIB Beacon Concept

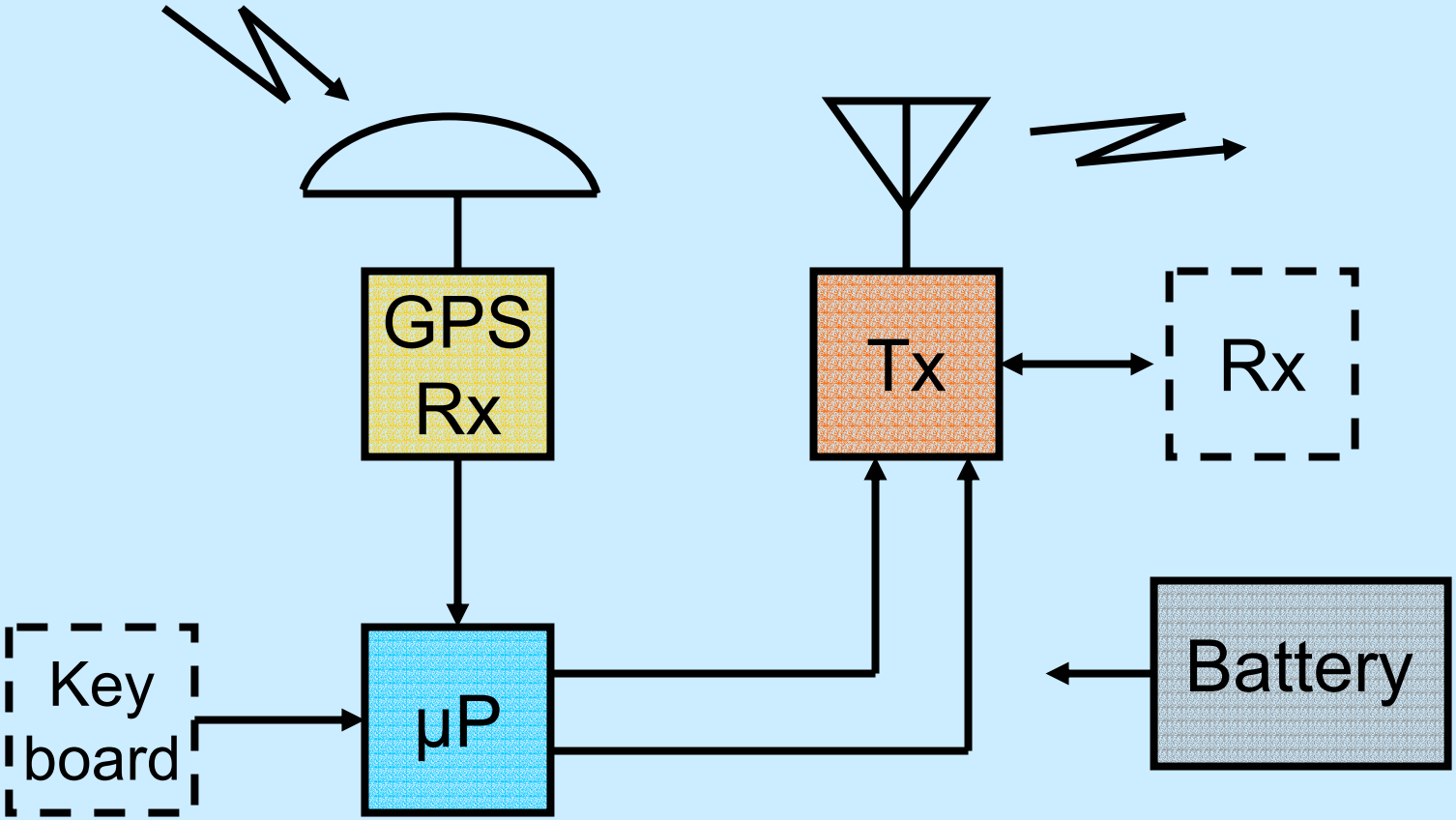
- Simplify and extend Mode-S transponder idea by using a Position Reporting and Identification Beacon (PRIB)
- Transmit encrypted aircraft ID
- Transmit GPS location
- Include ELT mode
- Automatic switch-on when aircraft in motion
- Battery power supply

PRIB Requirements

- GPS receiver and antenna for location data
- Beacon transmitter with burst mode
- 40 km line of sight range to receiver
- Encrypted aircraft identity
- On whenever aircraft moves
- Not easily defeated
- Battery operation
- Low cost



PRIB Sub-units



Next Generation Cell Phone (2004)

Next Generation Cell Phone

- Tri-band operation – 890 MHz, 1.8 - 2.0 GHz
- Integral GPS receiver
- 911 call transmits GPS coordinates
- Six integrated circuits
- Low current drain, high capacity battery
- Mass produced - reasonable cost
- Operation under stored program control

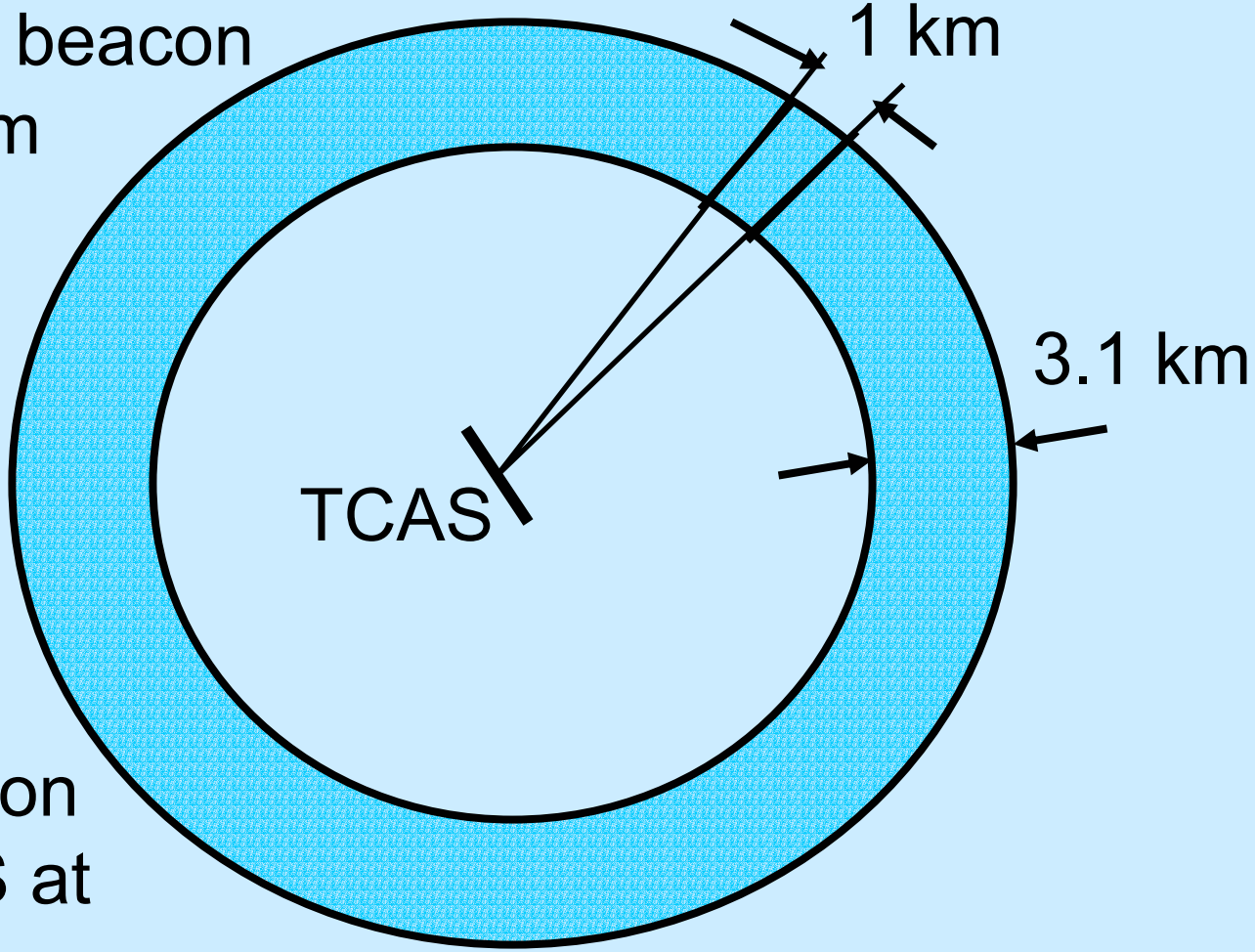
Next Generation Cell Phone

- Analog cellular telephone service (AMPS) is no longer supported by major companies
- Eventually 880 - 900 MHz band will be underused
- Ideal frequency for aircraft beacon
- Plenty of receive sites, especially around cities, linked to public telephone network

Locating Aircraft in IMC

- Smart Landing Facility requirements:
- Small GA airport with no secondary radar, no tower:
- Mode-S transponder (GPS transmission)
- TCAS on a stick
- Position Reporting Beacon (GPS transmission)

Resolution of
GPS + beacon
± 180 m



Nominal
Resolution
of TCAS at
10 km range

Beacon Characteristics

- Beacon transmits at random time with average rate of one packet every four seconds. Packet contains 108 bits

ID	Longitude	Latitude	Altitude	Checksum
24bits	28 bits	24 bits	16 bits	16 bits

Latitude and longitude resolution = 180 meters
Altitude resolution < 1m

Data Packet Simulations

- At 200 kbps, a data packet occupies 0.54 ms
- Average repetition time of 4 seconds
- Simulation results:
- 400 aircraft within 40 km of receiver
- Probability of packet collision is 0.25%
- Probability of two collisions is 0.00063%
- Reliability of data transfer within 8 seconds is
- 99.9994%

Beacon Modes

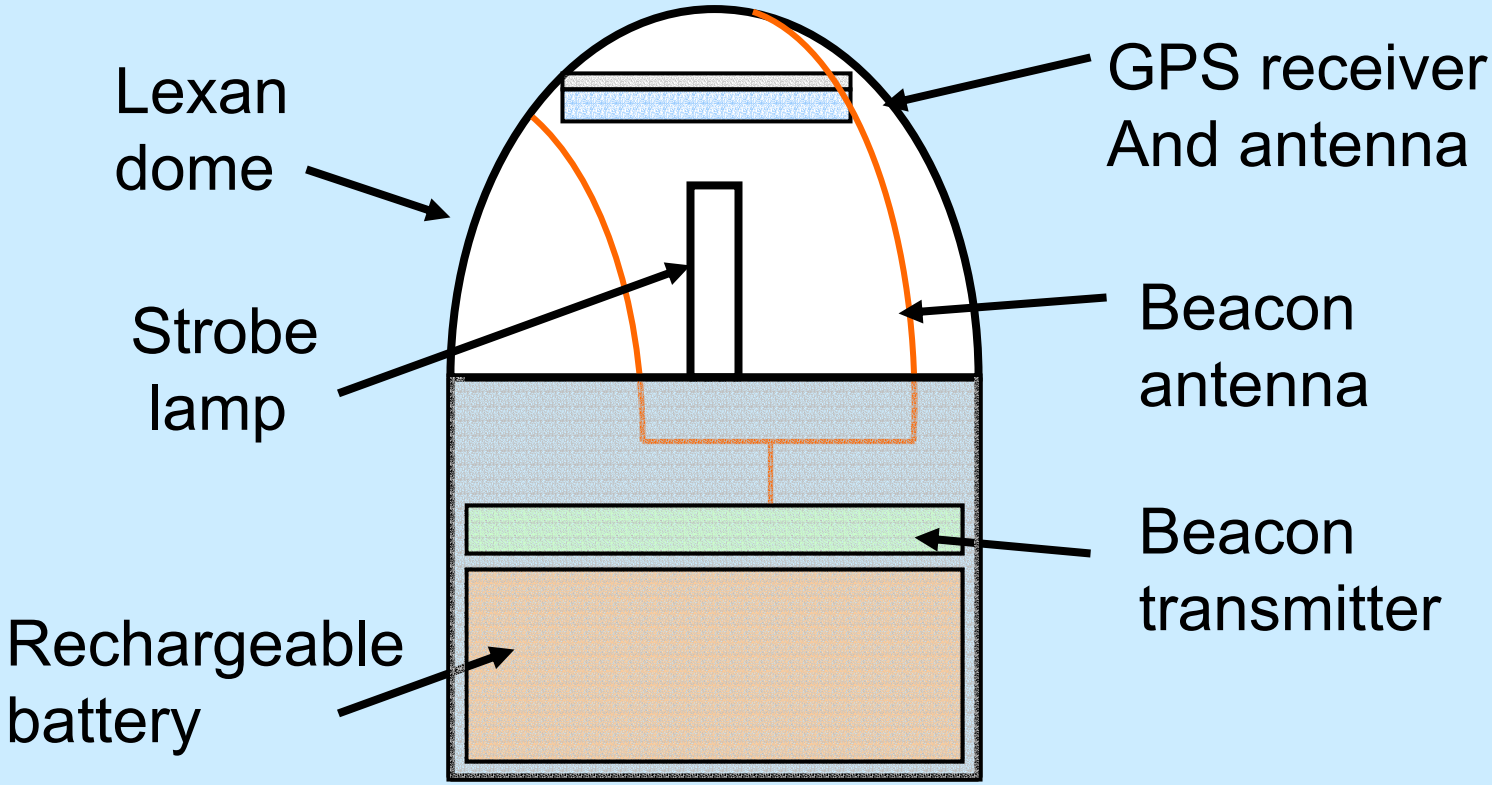
- Normal mode
- Power supplied by aircraft electrical system or rechargeable battery
- Disposable batteries if aircraft has no electrical system
- Beacon is turned on by aircraft motion, using magnetic field sensor
- Stays on for 30 minutes after aircraft stops

Beacon Modes

- ELT mode
- Power supplied by batteries
- Lifetime about 15 hours with 4 second cycle
- Beacon is turned on by G switch or pilot command
- Transmits emergency code, aircraft ID, location within 180 m

Possible Configuration

- Integrate radio beacon into anti-collision light
- Link operation of light and radio beacon as a measure to prevent tampering
- Light out: radio beacon not operating
  potentially hostile aircraft



Beacon System integrated into Anti-collision Light

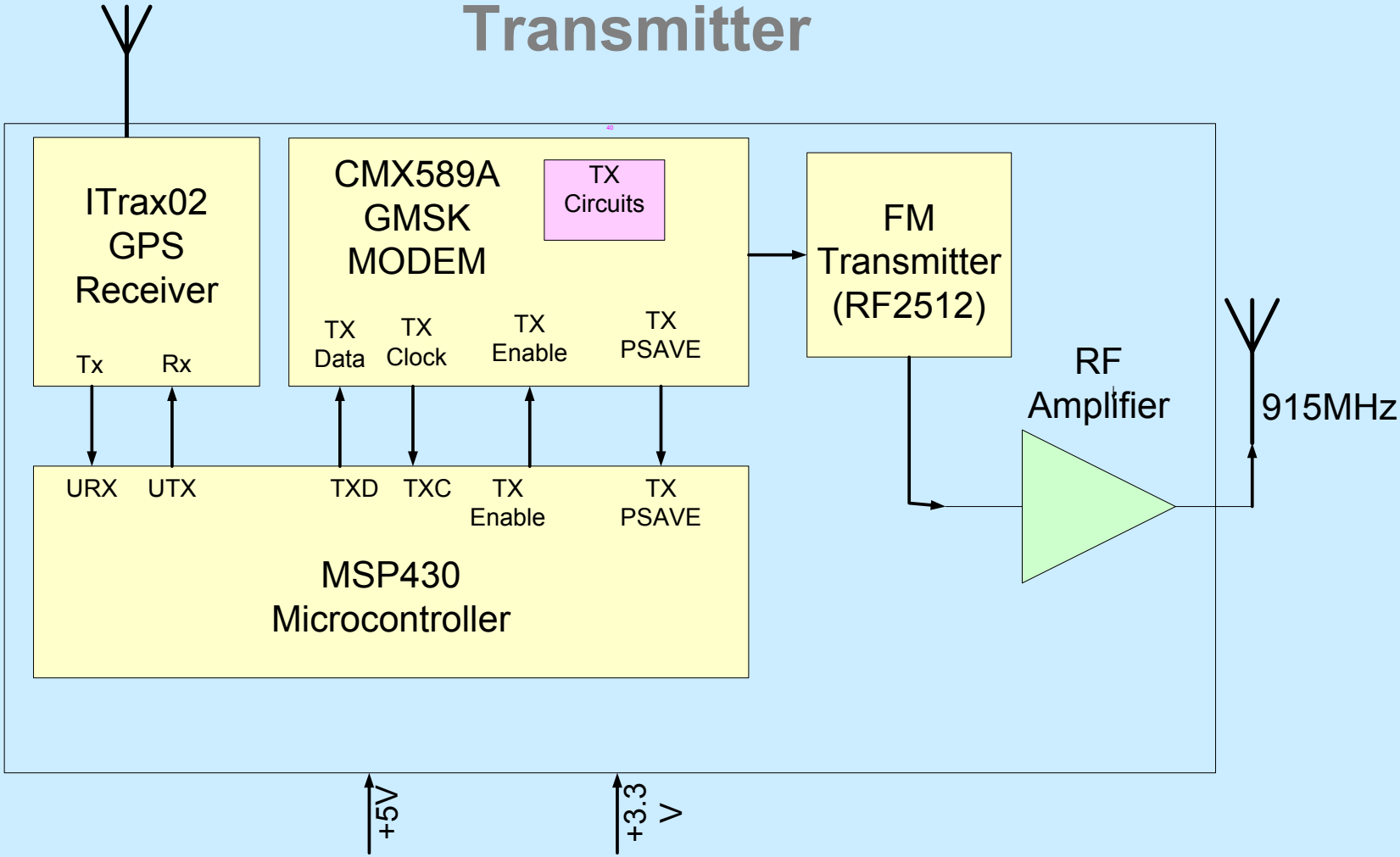
Link Budget to Base Station at 900 MHz

• Transmit Power: 1W	=	0 dBW
• Transmit Antenna Gain:	=	0 dB
• Receive Antenna Gain:	=	6 dB
• Path Loss (40km)	=	124 dB
• Miscellaneous Losses	=	3.5 dB
• **Received Power**	**=**	-127 dBW (-97dBm)
• Boltzman's Constant	=	-228.6 dBW/K/Hz
• Bandwidth (500kHz)	=	57 dBHz
• Noise Temp. (600K)	=	27.8 dBK
• **Noise Power**	=	-143.8 dBW
• **C/N**	**=**	**22.8 dB**

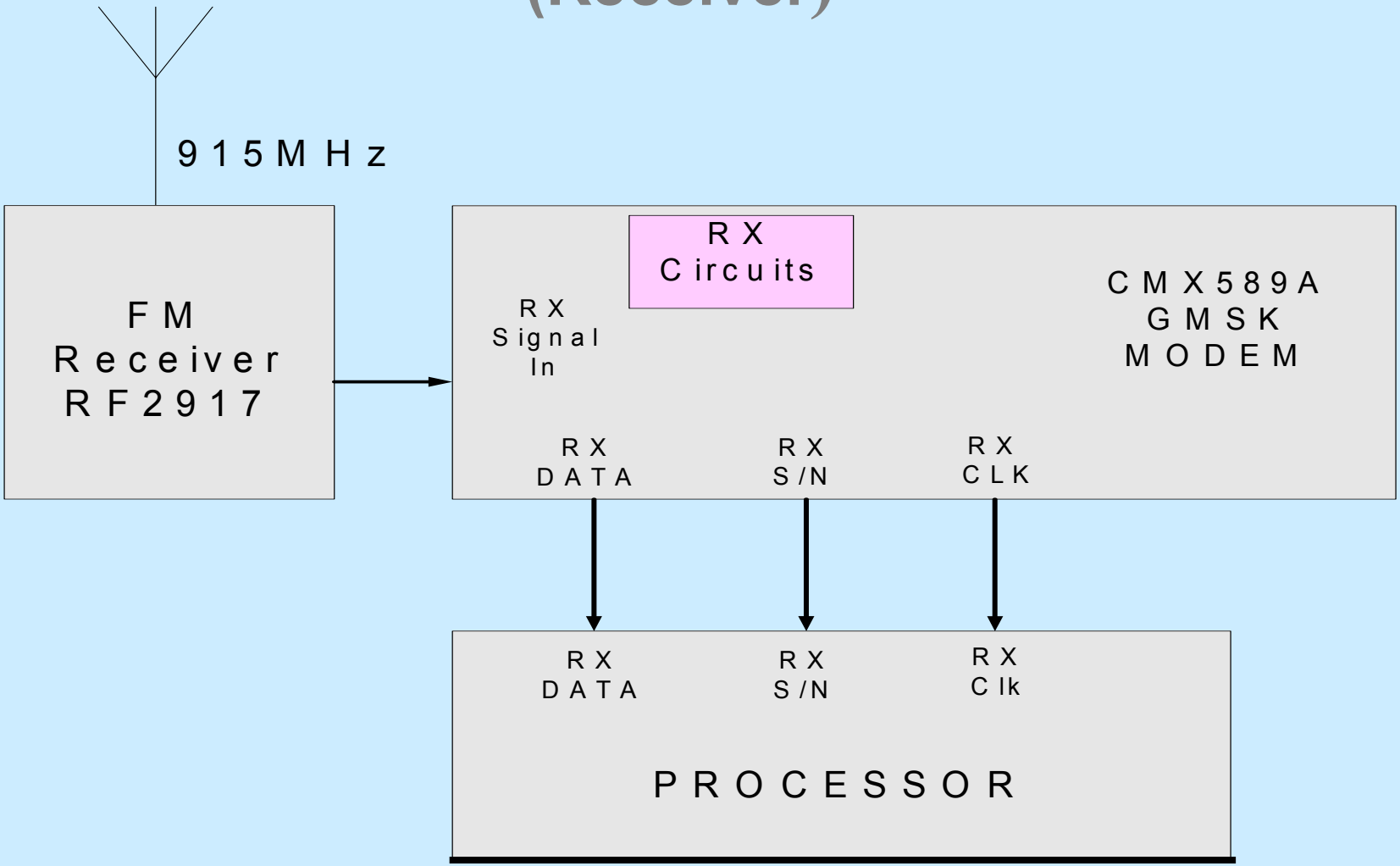
Demonstration Beacon System

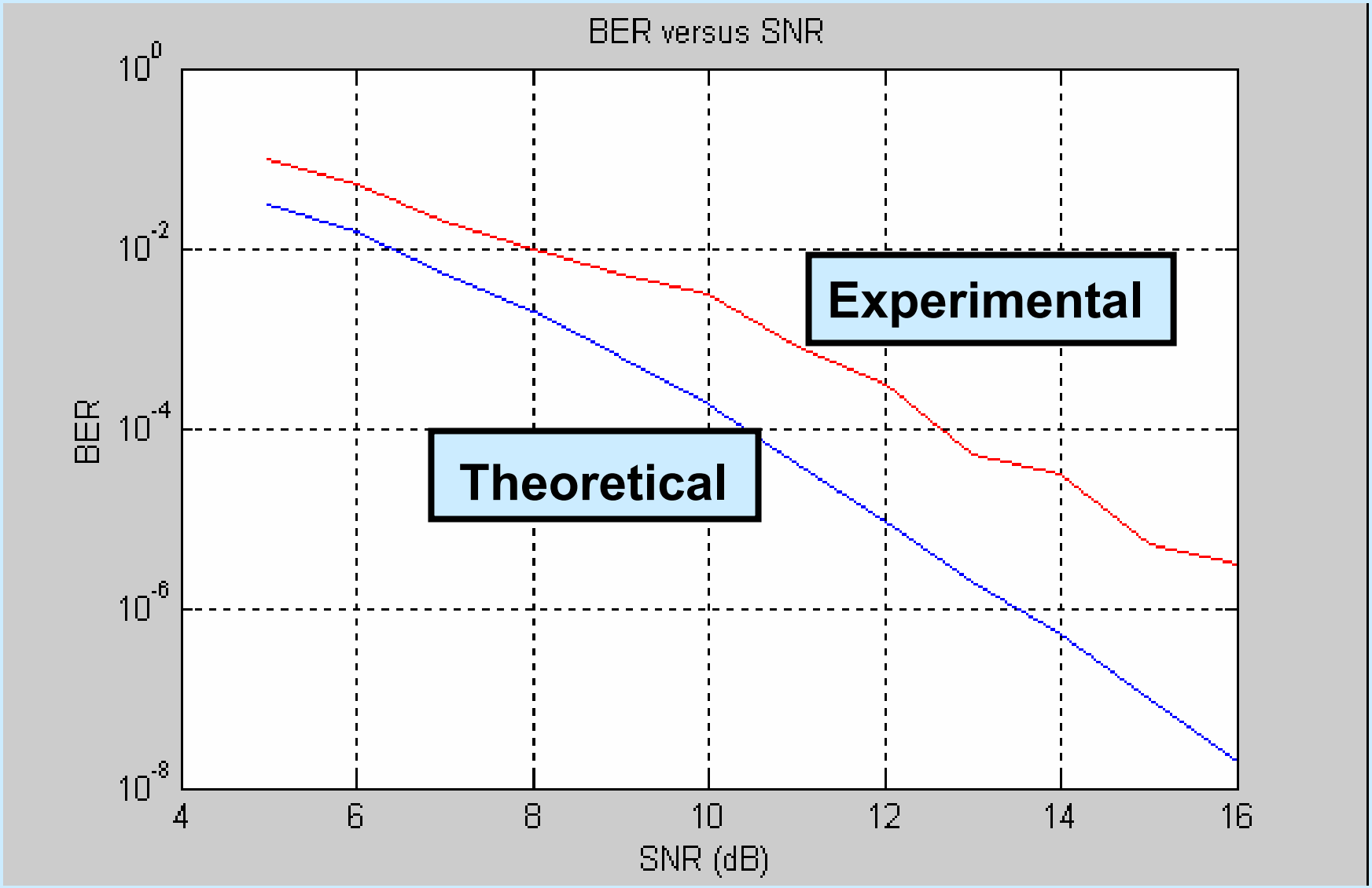
- Demonstration system built using COTS parts
- License-free 915 MHz band
- One watt FM transmitter with MSK modulation
- Single package GPS receiver
- Five integrated circuits, two antennas
- Excellent BER performance at low C/N ratios

Hardware Implementation Transmitter



Hardware Implementation (Receiver)

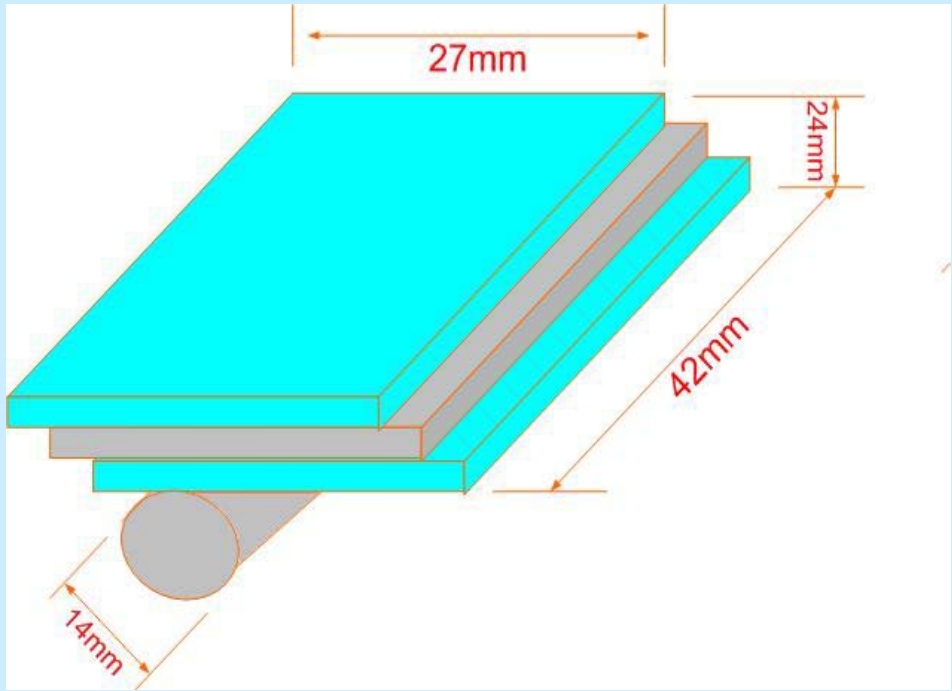




Demonstration System BER Performance

Demonstration Beacon System

Device	Price
GPS receiver	90.00
GPS antenna	10.00
MSP430	2.54
CMX589A	10.00
FM Trans. + RF ampl.	5.00
Charger +Up converter	8.00
Battery	3.27
PCB board x3	10.00
Total	**138.81**



Three PC Boards, one battery
Dimensions ~ 2” x 2” x 1”

Acknowledgement

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- Yuen On Lee is a Ph D student in the Bradley Department of Electrical and Computer Engineering at Virginia Tech

Conclusions

- Position reporting and identification beacon can serve dual roles
- Improved ELT sending GPS coordinates
- Tracking of aircraft at lower cost than mode-S transponder
- Beacon can be on whenever aircraft moves
- All transmitted data can be encrypted
- COTS approach offers acceptable pricing